BASSETT

The Development of a Recording Rail-Bond Tester

Railway Electrical Engineering

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THE DEVELOPMENT OF A RECORDING RAIL-BOND TESTER

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Cyrus White Bassett

ENTITLED The Development of a Recording Rail-bond Tester.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF B.S. in Railway Electrical Engineering.

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Instructor in Charge

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INTRODUCTION

The early history of electric traction was one of rapid development and expansion. Due to the extreme pressure attendant on the earlier installations little attention was paid to the economies of maintenance and operation. Recently, however, these matters have been receiving more nearly the attention they deserve. The question of track bond inspection has been rather neglected, for about the only means of testing is with a portable milli-voltmeter equipment, but this method is not at all efficient.

The early electric lines depended upon the earth return from the cars to the station, but the liability to electrolysis made it imperative to have a good return circuit. The rail itself is an excellent conductor, but the contact resistances of the fish-plates is so great as to amount to practically an open circuit, hence it is necessary to have a bonded joint of good conductivity. In England regulations were passed restricting the drop in the track return circuit to seven volts maximum. In some cities in the United States two overhead contact wires are required.

Rail bonding resolves itself into the problem of maintaining a low resistance track return, for when the track bonds are in poor condition a noticeable loss in economy of operation results. It has been noted that the power output required at a sub-station has been less on a wet day, owing to the better contact between

the rails and the ground.

RAIL-BOND TESTING METHODS

A frequent method of testing rails bonds is with a portable mill-voltmeter equipment. The usual process is to compare the resistance of the bond with the resistance of a certain length of solid rail, depending upon the existing current in the rail to give a reading. This is a slow and expensive process.

Another method for obtaining a general idea as to the condition of the track return is to measure its total resistance. If the resistance is excessive, each bond must be inspected separately.

The demand for a less laborious method of testing rail bonds led to the development of an automatic testing apparatus by A. B. Herrick. A test car was equipped with apparatus for obtaining the resistance of the bonds as it passed over them at a moderate speed. The commercial importance of this test car may be judged from the fact that over 90% of the electric lines in New England have been tested.

The Worcester Polytechnic Institute also has a test car equipped for testing rail bonds, and it is much in demand by the electric lines in that part of the country.

Recognizing the fact that such a testing equipment would have a commercial value, the Electric Railway Department of the University of Illinois undertook to equip their test car with the apparatus necessary to test rail bonds. The following is a description of the construction and testing of such an equipment.

GENERAL DESCRIPTION OF PRINCIPLES AND EQUIPMENT

The essential features of this equipment are as follows: A large local current is circulated between the two trucks of the car. The relative resistance of the rail and bond is measured by obtaining the voltage drop over that section of track between the trucks. It is necessary to maintain this local current in the track in order to obtain the bond resistance measurements entirely independant of the normal track current due to other cars on the line.

The local current was furnished, either by a low voltage generator or a storage battery. One of the trucks was insulated from the car body. The local current is conducted from the generator and battery through a reversing switch to the car trucks, and the circuit is completed through the rails.

The voltage drop is obtained by a recording milli-voltmeter connected to two brushes sliding on the rail. This drop gives the resistance of the rail bond in terms of the resistance of continuous rail. The conductivity of bonds is generally from one-fourth to one-half that of an equal length of rail. An average value of one-third may be assumed, hence, a rail bond one foot long would have a resistance equivalent to three feet of continuous rail. As the brushes slide over a predetermined length of continuous rail they measure its resistance; when they pass over a joint they measure the resistance of the same length of rail plus the resistance of the bond at the joint.

Two complete sets of recording instruments should be provided for measuring both rails simultaneously. The following description is that of one set only as there was not enough equipment available for two sets.

The voltage leads from the brushes are connected through a reversing switch and automatic cut out relay to the recording milli-voltmeter. The relay is necessary to protect the milli-voltmeter from injurious voltages and it may be set to operate at any desired voltage.

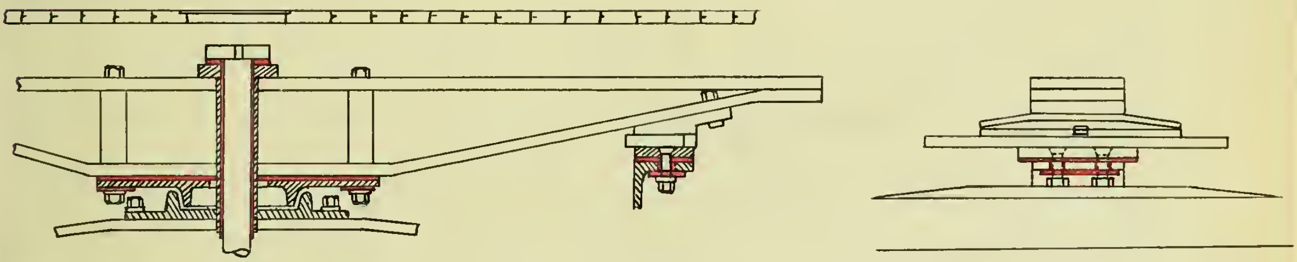
The movement of the milli-voltmeter needle is recorded by puncturing a moving strip of paper with a high tension spark. The record paper is positively driven in one direction by mechanism from one of the car axles through reversing gears. There is a definite ratio between the movement of the car and that of the paper. The location of poles along the track is indicated by means of a magnetically operated offset pen in conjunction with a consecutively numbering stamp. Other points are located by means of stamps and by marking the record.

In testing rail bonds it is necessary to operate the car at a slow speed. Operating at slow speeds continually with the normal control would overheat the resistance grids. To provide for continuous slow speed the main motor circuit was rewired so that the four motors can be connected in series.

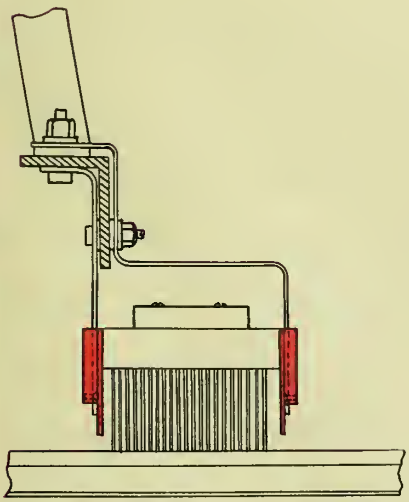
DETAILS OF CONSTRUCTION AND OPERATION

Truck Insulation.

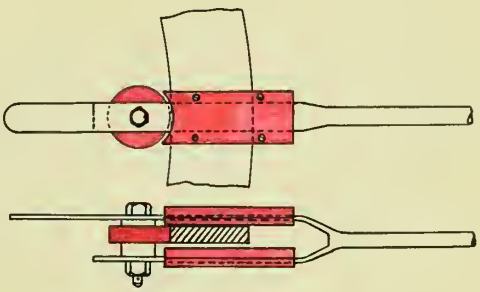
The circulation of the large local current from one truck to the other through the rails makes it necessary to electrically insulate one truck from the car body. On this type of car it was found necessary to insulate at four places, namely, the upper center plate, the king pin, the lower side bearings, and the brake rigging at the radius rod. The voltage brushes are also insulated from the truck. The insulating material throughout is fibre. The details of the insulation are shown by the following drawings:



CENTER BEARING, KING PIN AND SIDE BEARING INSULATION.



VOLTAGE DROP BRUSH.
INSULATION.



BRAKE RIGGING AT RADIUS BAR.
INSULATION.

Local Current Circuit.

The low tension current for use in the rails is furnished by a six cell storage battery and by a 100 amp. 3 volt Shunt generator. The capacity of each storage cell is 20 ampere-hours. The generator is belt driven by a 4 H.P. 500 volt D.C. Shunt motor. The battery and generator are connected in the circuit as shown on page 13. The battery alone furnished the current the greater part of the time. By means of a galvanized iron rheostat the current from the battery can be varied from 50 to 250 amperes.

The reverse switch is used to send the local current through the rails in the same direction as that of the normal track current. The current used in operating the car is also added to the local current by means of a double throw switch connecting the motor ground wire to either truck.

Potential Drop Circuit.

The function of this circuit is to obtain the voltage drop from the rail by means of two steel wire brushes and convey it to the recording milli-voltmeter. The brushes were most conveniently mounted in guides bolted to the inner end bar on each truck, thus making the distance between brushes equal to 12 feet. The brushes move vertically in the guides, thus allowing them to follow the track closely, and are weighted to give the necessary pressure to assure good contact with the rail. In rounding curves the brushes do not leave the track as they were mounted quite close to the wheels. The brushes were made by filling the heads of steel wire roughing brushes with babbit and embedding a

copper lead therein. Each brush is insulated from the truck.

On A. B. Herrick's test car the distance between brushes was 4 feet, while here a distance of twelve feet gave satisfactory results. This spacing has the advantage of permitting a higher maintained speed than the shorter spacing would allow for obtaining satisfactory milli-voltmeter readings.

The voltage drop current from the two brushes is led to a reversing switch; from there it separates into two circuits, one going through an automatic cut-out relay and the other to the recording milli-voltmeter through a contact on the armature of the relay.

The relay is designed to operate when the voltage drop across its terminals exceeds a certain predetermined amount. It is required to operate on a very low voltage. Hence the magnet coils are wound with a comparatively few number of turns of rather large cross-section wire. It was found necessary to construct the entire relay, and in this case each of the two coils was wound with 240 turns of No. 14 D.C.C. wire. The core is of soft iron wire to insure quick action of the armature. The tension on the armature is regulated by a spring.

The circuit to the milli-voltmeter is completed through a contact on the relay armature. An excessive voltage drop causes the armature to be attracted; instantly opening the contact and cutting the milli-voltmeter out of the circuit.

To properly complete the function of the relay the armature when attracted should close a circuit actuating an offset pen for marking "open" or high resistance bonds.

The construction of this relay was not all that could be desired, as the means were not at hand to make so delicate an instrument. However, it would promptly cut out the milli-voltmeter on voltages exceeding 200 milli-volts.

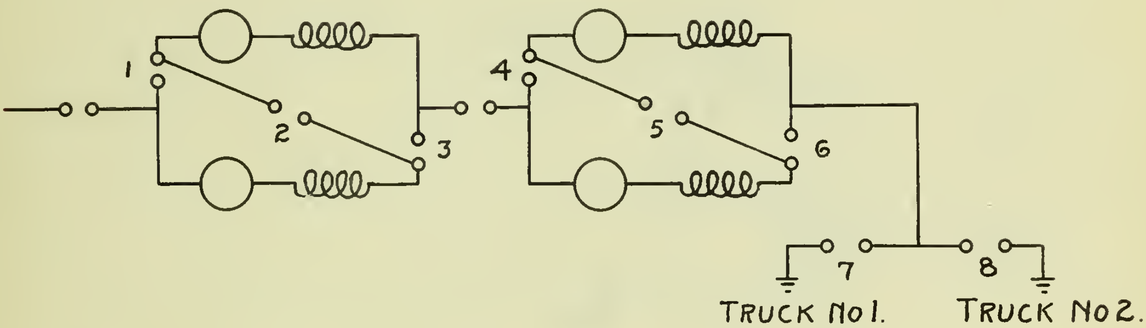
High Tension Circuit.

For all voltage drops, up to and including 75 milli-volts, the movement of the milli-voltmeter needle is recorded by means of a high tension spark. The needle is insulated from the milli-voltmeter movement by glass tubing. The high tension spark is brought from the induction coil to a copper strip placed just below the needle and about one inch from the tip. The spark jumps from the copper strip to the aluminum pointed needle, passes to the tip, and from there jumps to the end of the nearest one of a number of copper wires insulated from each other, and extending in the form of an arc just under the tip of the needle throughout its whole travel. The copper wires terminate in a straight row in a block of fibre placed slightly above the record paper. Thus as the needle swings the spark travels back and forth, and issues from the wires in the fibre block. The spark jumps to a brass plate over which the record paper is drawn and thence returns to the induction coil through a wire grounded on the brass plate. The spark in its passage from the wire ends to the brass plate punctures the record, thus giving an indication of the needle, which in turn indicates the voltage drop.

A Max Kohl induction coil is used. The primary current is obtained from a storage battery and is controlled by a rheostat. The spark from the secondary gives a clearly punctured record.

Car Speed.

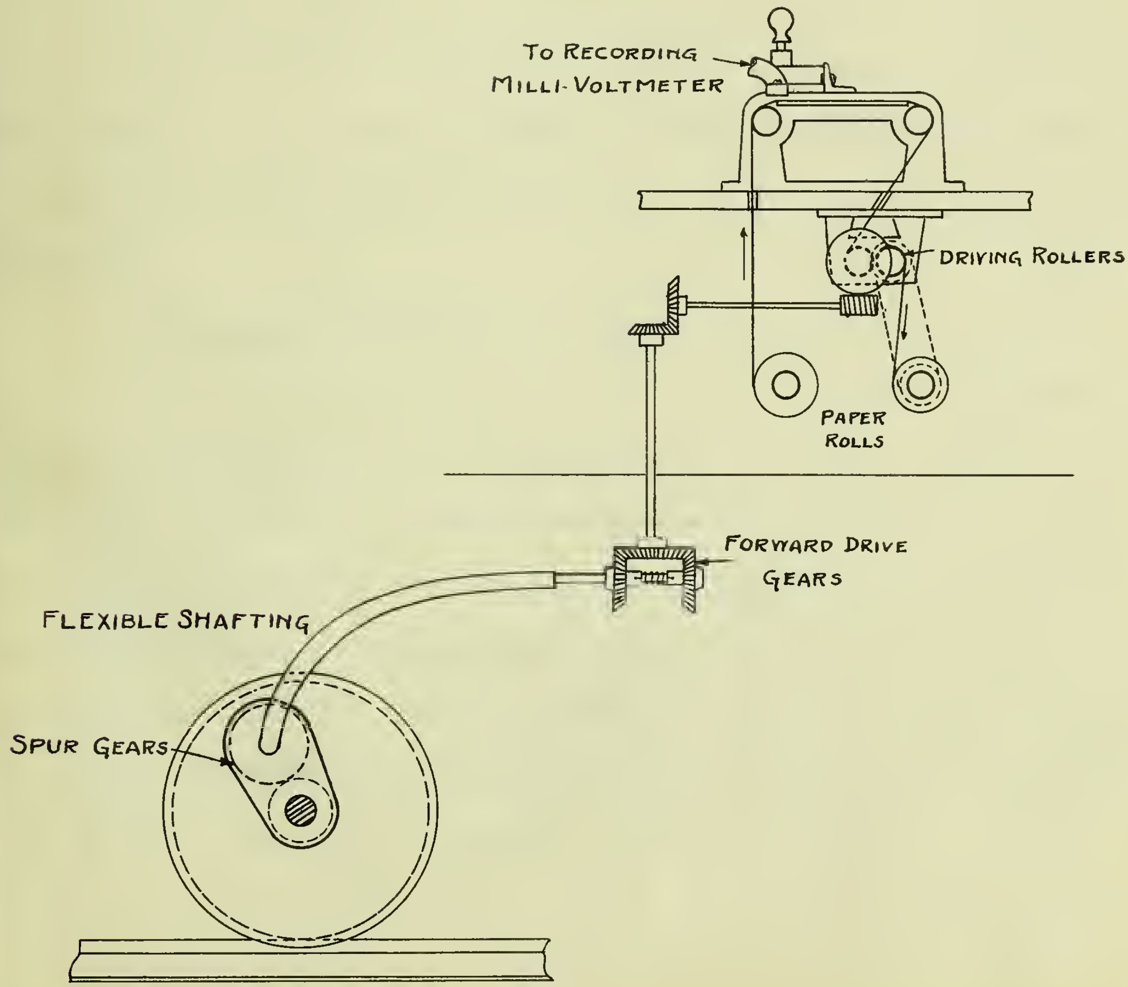
To provide for either normal car operation or for the slower continuous speed required when testing rail bonds, necessitated the rewiring of the main motor circuit. Thus opening switches 1, 3, 4 and 6, and closing 2 and 5, (see diagram) puts the four motors in series on the line. This arrangement gives a continuous running speed of, approximately one-fourth full speed, or 12 M.P.H. By closing either switch 7 or 8, the main car current could be sent to either truck to add to the local circulating current in the track.



While a speed of 12 M.P.H. is found to give satisfactory results with a twelve foot spacing between the voltage brushes, if it were found desirable to decrease the spacing in order to secure greater sensitiveness, a lower speed would be necessary to give sufficient time for the needle to record the full drop across the bond. However, the twelve foot spacing is better than a shorter spacing for use on poorly bonded tracks, as it gives a large range and great accuracy is not required.

Recording Mechanism.

The record is made on a continuous strip of paper 10 inches wide. It is positively moved in one direction irrespective of the car movement. The paper comes from a roller under the table, up through the table and over the brass plate bridge; then down through the table to two driving rollers and finally is rewound upon the receiving roll. The driving rollers are operated from the car axle by means of gears and flexible shafting. The gear ratio is such that 90 feet of car travel moves the paper through a distance of one inch. The driving mechanism is shown by the following drawing:



The Record.

Page 14 is a sample section from a record made on the road. It is a record of one rail only. The trolley poles are indicated by the offsets in the line, and the pole offsets are stamped with numbers, starting from some one pole whose position is easily located. Hence the position of any high resistance bond may be determined by reference to the pole offsets and the corresponding number which is referred to some starting point. Other locating points, as crossings, curves, sidings, stations, etc. may be marked with pencil as passed.

The ordinate R represents the voltage drop on 12 feet of continuous rail, while T represents the voltage drop over 12 feet of rail and the included bond. $\frac{B}{R}$ x 12 gives the equivalent resistance of the bond in terms of feet of continuous rail. This is based on the assumption that the current in the rail remains constant.

Division of Current in Rails.

The sample test record shows that the deflection, R, on continuous rail and, therefore, the current in this rail remains practically constant as long as a bond is not included in the circuit. However, it is evident that the introduction of a high resistance bond into the circuit will decrease the current. The amount of decrease in the current depends upon the ratio of the bond resistance to the total resistance of the circuit between the trucks, which includes the contact resistances between the wheels and rails, and also the rail resistance and the bond resistance. This ratio is very small as was shown by

the fact that during tests the voltage between trucks remained fairly constant at 1.2 volts, with a local battery current of 120 amperes, and 40 amperes from the main motors flowing from one of the trucks into and through the rails in the same direction as the battery current.

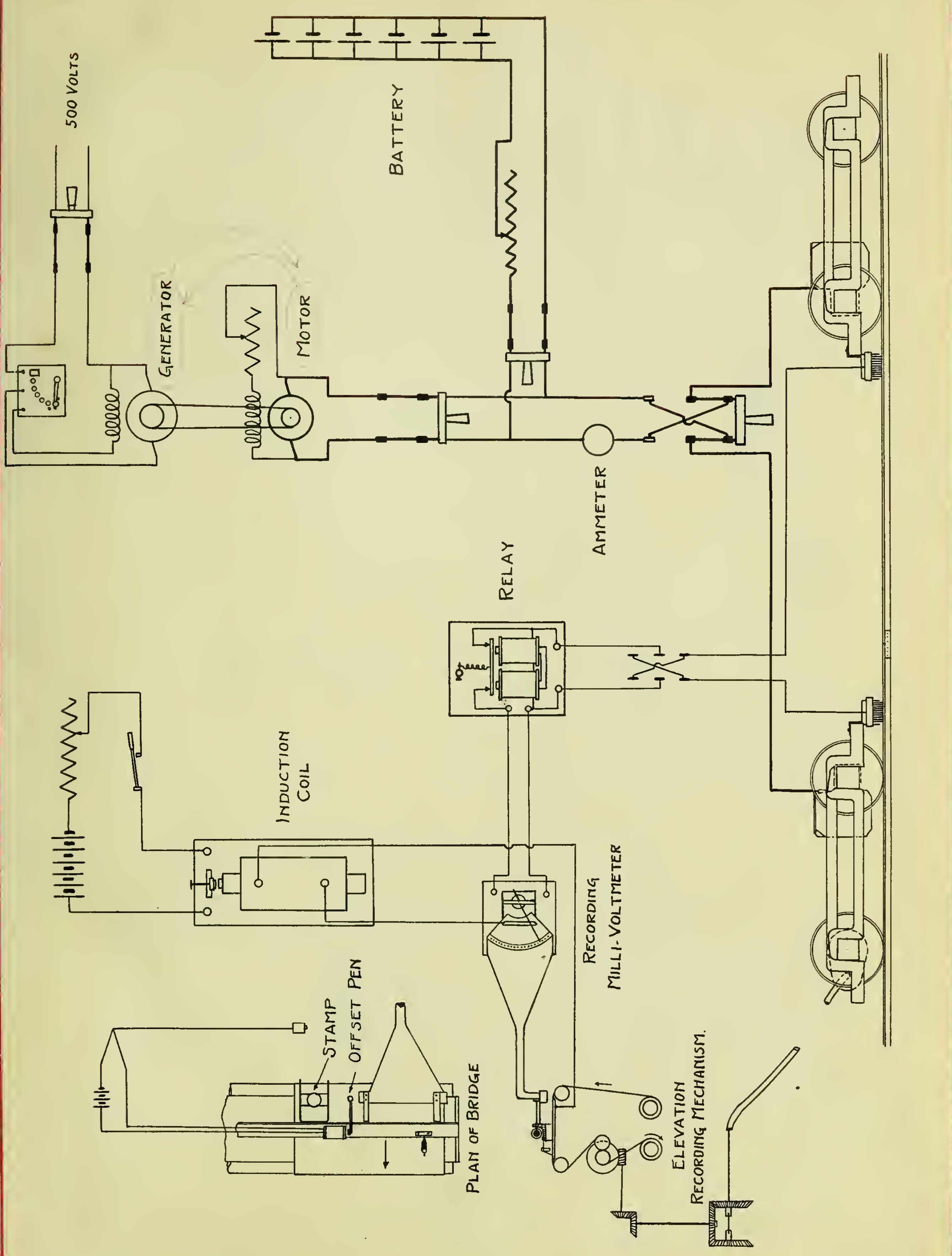
Tests made with the car standing show that the greater part of this drop is due to the contact resistance between the wheels and rails. There is a certain amount of drop due to the inductance in the wheels and rails owing to the fact that this magnetic circuit through which the current flows is continually changing as the car advances.

Both the contact resistance and the inductive effect tend to prevent the unequal division of current in the rails.

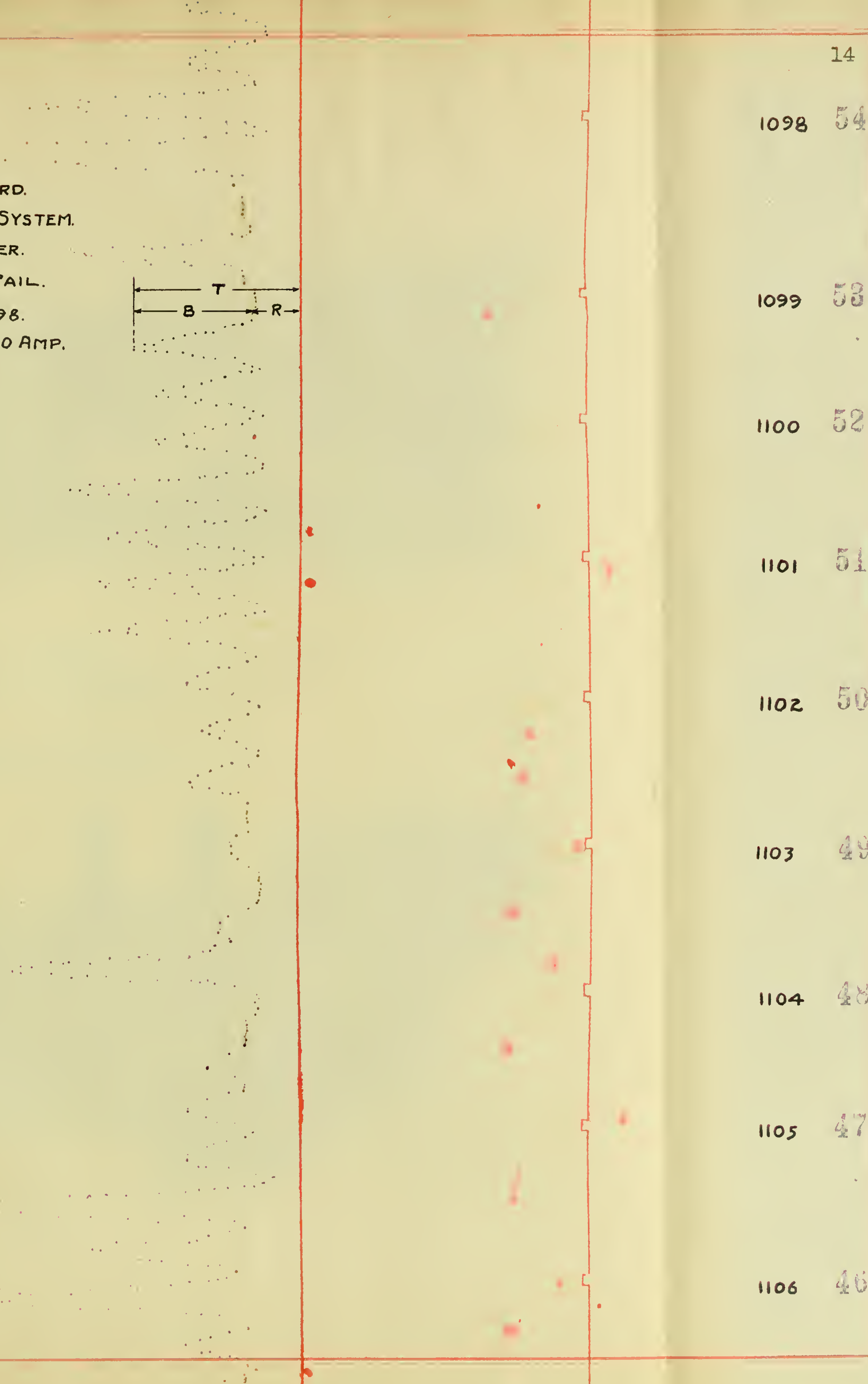
The full scale deflection of the recording milli-voltmeter is only 75 milli-volts, and it takes a high resistance bond to give this deflection. Hence the bond resistance is never great enough, when compared with the contact resistance between the wheels and rails, and the inductance, to materially affect the division of current between the two rails.

Conclusion.

In the few tests that have been made since the completion of the apparatus, it has been impossible to obtain accurate measurements of the resistance of bonds. However, the records made are of commercial value in that they show the relative condition of different sections of the track and indicate which bonds are in the most urgent need of attention.


500 Volts
Generator
Motor
Battery
Ammeter
Relay
Induction Coil
Recording Milli-Voltmeter
Stamp
Offset Pen
Plan of Bridge
Elevation Recording Mechanism.

Rail Bond Record.
Illinois Traction System.
Ogden to Glover.
Test on South Rail.
Poles #1106 to #1098.
Local Current. 40 Amp.
May 15, 1911.




tor Generator Set
and
Battery

Recording Equipment